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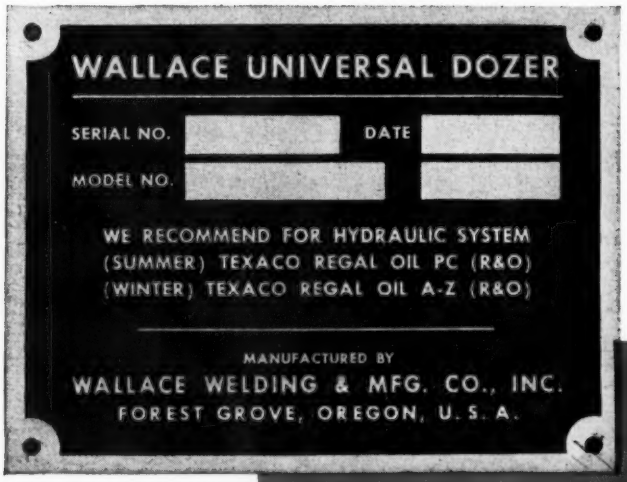
Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

HYDRAULIC POWER
AND THE
INDUSTRIAL TRUCK

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS



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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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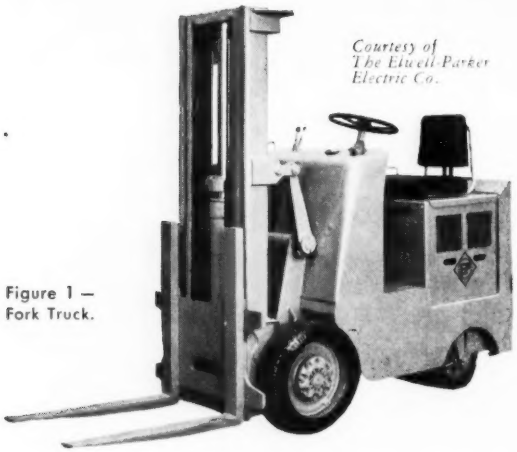
Hydraulic Power and the Industrial Truck

WHAT single factor or requirement is most essential if our industrial productive capacity is to continue at its present high level, or possibly even increase? Obviously there is no simple answer to this question. No one factor can be singled out as being THE most important. Large productive capacity as we know it today depends upon the smooth integration of many different, individual factors. Appropriate raw materials must be available in quantity. Machines and auxiliary equipment of all kinds are needed to convert the raw materials into the endless variety of products which have come to be necessities in our daily lives and for our military purposes. Vast quantities of power must be generated to turn the wheels of industry and operate the machines. Transportation facilities are required which will speed the raw materials and finished products to and from the plants and factories. These are some of the factors which most of us recognize as being "musts," for large scale industrial production.

However, there is another requirement equally as important and essential as those just mentioned but for the most part wholly unrecognized and unappreciated by the average person. This is the need for smooth, quick and efficient handling of all goods and materials. What does it matter that speedy facilities are available for transporting raw materials, supplies and finished products if the handling methods used in storage, loading, unloading and distribution are laborious, time consuming and inefficient? What does it matter that machines can turn out products at record breaking rates if they must be shut down periodically because materials to be fed to the machines are not on-hand when needed or because goods coming from the production line are allowed to pile up in the immediate vicinity and create a congested condition? Materials handling must be regarded as a key factor in industry today if the production lines are to operate at maximum efficiency and capacity.

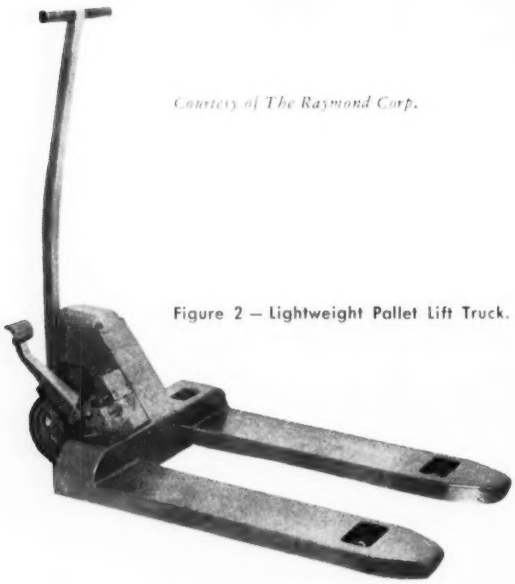
Even in days of yore, prior to the advent of the industrial era, materials handling was a matter of great importance and one which warranted considerable attention. How many times have we sung or listened to the familiar strains of the so-called work songs without realizing that they were intended to serve a more definite and useful purpose than merely as a source of entertainment and pleasure? In those days man was the backbone of all handling operations. In many instances it was necessary for men to work together as a unit, passing goods from one to the other in loading or unloading operations, or pulling and lifting together in operations requiring consolidated effort. The principle of music while you work had been discovered long ago when it was observed that rhythm imparted a unity to the movements and actions of a group which enabled them to perform the task at hand more quickly, easily and efficiently. Music more than anything else gave their actions the joint effort needed to transform a disorganized group of individuals into a smooth functioning unit.

In contrast to the not too distant past, mechanization is now obviously indispensable in practically every manufacturing operation. Likewise, transpor-



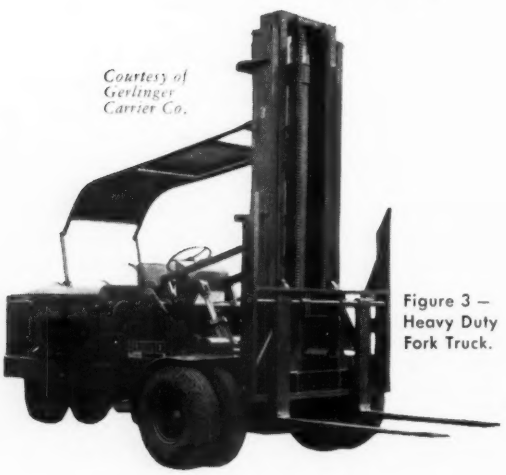
Courtesy of The Elwell-Parker Electric Co.

Figure 1 — Fork Truck.



Courtesy of The Raymond Corp.

Figure 2 — Lightweight Pallet Lift Truck.



Courtesy of Gerlinger Carrier Co.

Figure 3 — Heavy Duty Fork Truck.

tation in the United States has become almost 100 per cent mechanized. Use of horses today in competition with power driven trains, highway trucks and planes, or the use of sails on ships is unthinkable. For a while development and progress in materials handling did not keep pace with the corresponding advances in the other phases of industry. Time and time again delays were encountered due to inadequate and inefficient methods for handling goods and materials.

This condition is now rapidly being rectified. Recognition of the variety and scope of opportunities for improving handling methods has led numerous industries to make materials handling an active function of management. Keeping machines and machine operators producing full-time by maintaining a smooth, even flow of materials to and from machines and other processing operations offers one of the greatest opportunities to increase manufacturing efficiency. Consequently mechanization of handling operations has been adopted in many industrial plants and warehouses. It is not confined to the production line but starts on incoming freight platforms, includes all handling to, from and in temporary storage areas and stockrooms and ends in the outgoing cars or trucks that remove finished products and waste materials.

The success of mechanized materials handling operations within plants and factories has been so great that they are being extended to other phases of industry. Suppliers of raw materials and distributors of finished commodities are now adapting such techniques to their own handling problems.

The success of mechanized materials handling depends on two basic elements — namely the unit load and the industrial truck.

Unit Load and Industrial Truck Defined

Unit loads may be defined as quantities of material assembled and sufficiently secured together to permit handling and stacking by means of power equipment for loading, shipping and unloading as a unit. They may be formed on trailers, skids, pallets or by any unitizing method that makes materials accessible in large units for mechanized handling.

The term industrial truck is generally applied to a self-propelled vehicle that carries the load directly. In contrast to this is the tractor which is not designed to carry any load itself but can push or pull other conveyances which do carry the load.

Development of the Industrial Truck

In the year 1906 more speed and power were required for handling an increasing volume of baggage at a Philadelphia railroad station. To satisfy this need, an electric motor and storage battery were installed beneath the platform of an ordinary

baggage truck and controls were placed on the steering handle. This event is generally regarded as marking the birth of the powered industrial truck industry.

Although this use of battery power was a substantial improvement, the first industrial trucks still had to be manually loaded and unloaded. It wasn't until about ten years later that the power-operated low-lift platform truck made its first appearance. This equipment permitted the first real mechanized handling. The trucks could pick-up, carry, and deposit loaded skid platforms, skid racks, or skid bins without rehandling.

This development was followed in about 1918 by the high-lift platform truck which was so designed that loads could be lifted high enough to permit stacking, thus saving valuable floor space. The practicability of this handling system was so obvious that the next efforts were directed toward a system suitable for still broader applications.

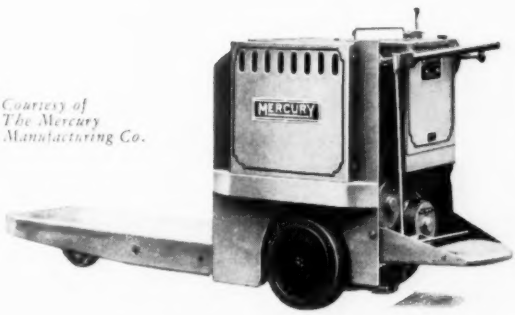
The basis for such a system was the fork truck developed in the early 1920's. It was realized that if forks or prongs were used as the lifting and load carrying media, they could chisel under some loads or pick-up others if they rested merely on relatively cheap pallets rather than the expensive skids.

The first fork trucks lifted the loads straight up and down. It was soon apparent that the loads could be carried more safely if the forks could be tilted back and unloaded more easily if they could be tilted forward. Thus the tilting fork truck was developed in the late 1920's.

From these modest beginnings the industrial truck industry has grown to the stage where its yearly production is in excess of $200,000,000, and it continues to expand. Developments and improvements have been too numerous to mention. Trucks with maximum load capacities ranging from ½ ton to more than 50 tons are now available to satisfy practically every material handling problem that may arise.

Courtesy of Clark Equipment Co.

Figure 4 — Fork Truck.



Courtesy of The Mercury Manufacturing Co.

Figure 5 — Low Lift Platform Truck.

PRINCIPAL TYPES OF INDUSTRIAL TRUCKS

The types of industrial trucks most commonly employed and their prime functions are described briefly as follows:

Low-Lift Platform Truck

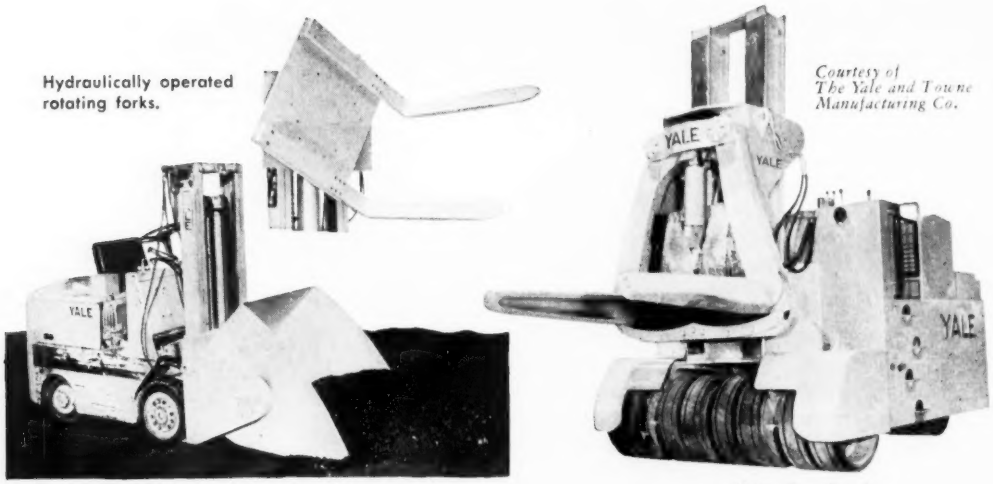
These are most frequently used with skids or skid-bins. Their ability to keep production machines operating by moving heavy loads in congested areas where lifting power is needed to take the load off the floor is an outstanding advantage.

High-Lift Platform Truck

In addition to performing all the functions of the low-lift truck, this truck can stack heavy loads on skids ceiling high, thus saving floor space.

Courtesy of The Towmotor Corp.

Figure 6 — Motorized Pallet Lift Truck.



Fork Lift Truck with hydraulically operated scoop.

40 ton Ram Truck.

Figure 7

Motorized Pallet Truck

Although motor driven, these are similar to the hand pallet trucks and are led by an operator on foot. They are available in either a low or high-lift version, and the lifting mechanism is operated by foot or by motor.

Ram Truck

These are particularly suited for handling operations in steel mills where an individual item to be moved may weigh as much as 50 tons.

Fork Truck

This truck is undoubtedly the most versatile tool for industrial materials handling, and can perform every handling operation in receiving, processing, assembling, storing, packing and shipping. At first the fork trucks were designed to handle skids and pallets and were provided only with raising and lowering motion of the carriage and the in-and-out tilting motion of the mast. A truck of this type is today generally regarded as a standard model. Most of them are equipped with telescopic upright sections which permit the truck to pass through areas of low clearance, yet with uprights telescoped, to stack materials at heights considerably greater than the truck itself. Such trucks also have a maximum amount of "free-lift," which is the distance the load can be raised from the ground before the uprights or structures begin to rise. This is essential for stacking and tiering in boxcars and low ceiling warehouses.

Vast assortments of special accessories are now available for use on a standard truck, making its versatility practically unlimited. Some of the special auxiliary features adaptable to the fork truck include the following: scoops, shovels and bins for handling bulk material; clamping devices for handling drums, paper rolls, bales and light, bulky cartoned merchandise; side-shifting devices for accurately spotting loads; push-off and pull-on devices for automatic loading or unloading; revolving and rotating heads of special design for upending loads or turning them on their side. These are only a few of the special accessories available, but serve to indicate the degree of flexibility that can be imparted to the fork truck. Its versatility is such that in some instances it is almost human. For example, a fork truck equipped with a paper roll clamp can pick up a roll four feet in diameter and weighing two tons, regardless of whether it is standing vertical or lying horizontal. It can rotate it, move it up and down or shift it sideways, and place it accurately on a given spot.

MOTIVE POWER

In addition to being characterized by the nature of their handling functions, the industrial trucks are also identified according to the type of motive power employed. Although a discussion of motive power is outside the scope of this article, mention should be made that the trucks may be either electric, gasoline, or diesel powered, and some are available that operate on propane.

The electric truck is powered by a storage battery and a direct-current motor.

The gasoline truck may be either a "gas-electric" type, powered by an engine-generator and a direct-current motor, or a "gas-mechanical" type, powered by a gasoline engine through a mechanical transmission.

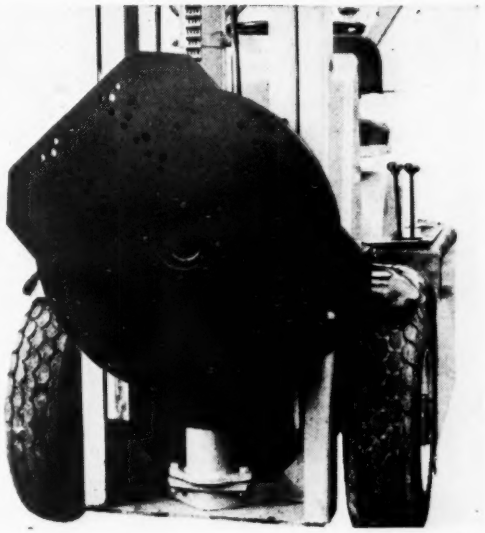
As might be expected one type of truck will have advantages over the others in certain circumstances and the choice of one type in preference to another will depend upon a number of factors, including

the nature of the service to which it will be put and the overall economics of initial cost and maintenance.

HYDRAULIC POWER FOR MATERIALS HANDLING

The importance of the industrial truck to materials handling operations has been stressed and mention has been made of the variety of functions it can perform, but so far, no indication has been given as to the means by which these functions are accomplished. A casual observer watching an operator put an industrial truck through its paces merely by finger-tip manipulation of a lever or two must surely be convinced that magic is involved.

Although the many operations performed by the industrial truck could be accomplished by electrical or mechanical devices, hydraulic power is by far the best suited and the most adaptable, particularly from the standpoint of economics of design and simplicity of construction. Hydraulics offers a relatively simple method of applying great forces with a flexibility of controls that is astounding and has many inherent advantages over other types of power. Most hydraulic systems are relatively simple in design. The need for complicated systems of gears, cams and levers is eliminated. Motion can be transmitted without the slack inherent in the use of all solid machine parts. The liquids used are not subject to breakage as are mechanical parts, and due to incorporated self-lubrication characteristics, wear of moving parts is reduced. The component parts of a hydraulic system can be located at widely separated points, and the forces generated rapidly and transmitted over considerable distances with small loss. The forces can be efficiently carried up and down or around corners without the aid of complicated mechanisms. Very large forces can be controlled by much smaller ones and can be transmitted through comparatively small pipes and orifices. A hydraulic system can provide smooth, flexible, uniform action without vibration and unaffected by variations of load. Hydraulic systems can also provide widely variable motions, and can automatically be protected against breakdown and strain.

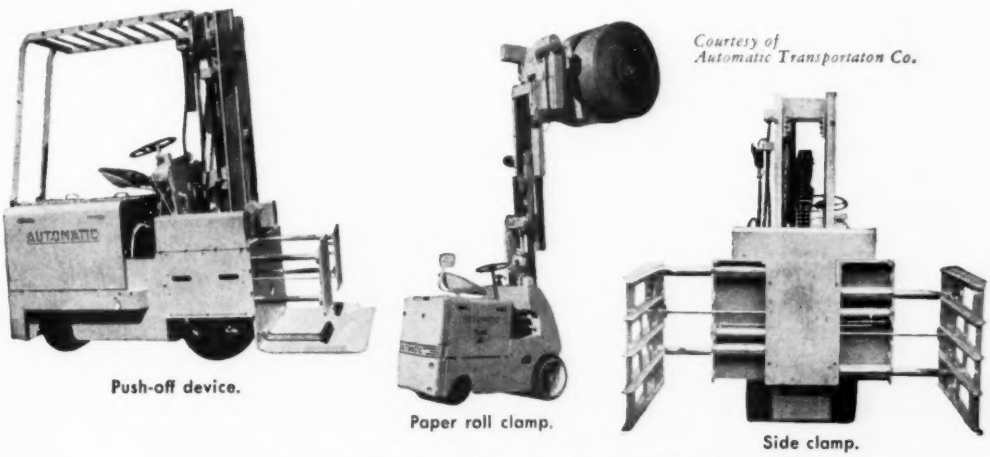


Courtesy of Hyster Co.

Figure 8 — Hydraulically operated revolving apron for rotating attachments.

ADVANTAGES OF HYDRAULIC POWER TO THE INDUSTRIAL TRUCK

An industrial truck usually will be required to perform at least two functions, such as hoist, tilt, clamp, rotate, push-off, pull-on, etc., and frequently three, four or even five such functions. The operation of each function by electrical or mechanical means would necessitate the use of several



Courtesy of Automatic Transportaton Co.

Push-off device. **Paper roll clamp.** **Side clamp.**

Figure 9 — Fork Lift Truck with hydraulically operated attachments.

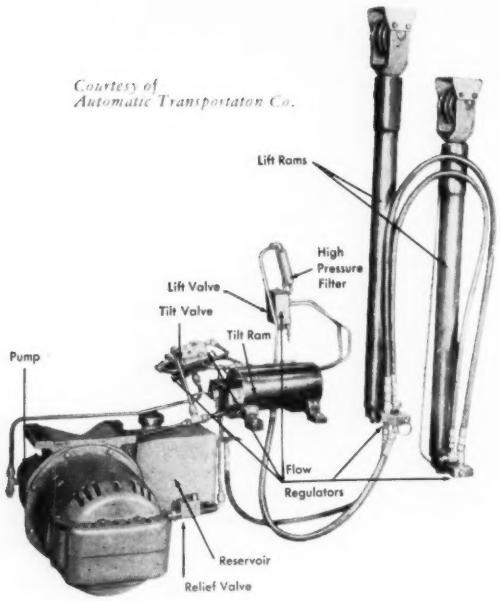


Figure 10 — Hydraulic System in an Automatic Fork Lift Truck.

motors, multiple control devices, gear reduction units and other auxiliary equipment, all of which are relatively expensive both to install and to maintain. Also, it is essential that the overall size of an industrial truck be held to an absolute minimum for easy maneuverability and use in confined areas. The large amount of space required for the equipment needed for electrical or mechanical transmission of power would be most undesirable. With a hydraulic system, however, a single pump can supply the source of all the power required and a suitable system of valves, operated by simple control levers, enables the power to be directed to any of the multiple functions. The valve arrangement is such that when the power is diverted to any one operation, the others are not disturbed but remain fixed.

Industrial truck operations also involve some other essential requirements:

Overloading must be prevented — a truck designed for a given capacity should never carry loads in excess of that capacity.

Control must be exercised over the pressures developed in some of the functional operations — in clamping a fragile item enough pressure should be exerted to grasp it firmly but not so much as to crush it.

Motion of the various materials handling functions must be limited and controlled to prevent over-travel and subsequent damage to the truck— for example, in hoisting a load, the lifting power should be discontinued when the load has been raised to the maximum allowable height.

Hydraulics permits these requirements to be met very simply by the use of pressure relief valves set to pre-determined values and placed at convenient locations within the system. Elaborate mechanisms at considerable cost would be necessary to obtain these same features by other means.

Hydraulics also allows precise control over the speed with which the handling functions can be performed. The simple movement of a valve will adjust the rate at which a load can be raised or lowered.

Finally the safety feature of hydraulic power is most attractive. The danger of a heavy load accidentally dropping and causing injury is almost negligible. If perchance a line in the system should break when the load is elevated, appropriate flow or check valves located within the hoist cylinder will either keep the load suspended or allow it to be lowered gently.

These are just some of the reasons why the industrial truck industry is relying more and more on hydraulics as the backbone of attachment design.

FUNDAMENTALS OF HYDRAULIC SYSTEMS

Before discussing the application of hydraulics to the materials handling operations of the industrial truck, it might be advisable to review briefly some of the fundamentals.

All modern hydraulic systems are based on Pascal's discovery in 1653 that "Pressure exerted on a confined liquid is transmitted undiminished in all directions and acts with equal force on all equal areas." Since liquids are essentially incompressible, the pressure applied to a liquid at one point will be transmitted to any point within reach of the liquid. A hydraulic system, then, is an arrangement whereby pressure applied to a liquid can be converted into mechanical work. Fundamentally it consists of the fluid, a unit for generating force or energizing the fluid, suitable means for containing and transmitting the energized fluid, and units for converting the energy in the fluid into mechanical work. In order for any system to be operative, of

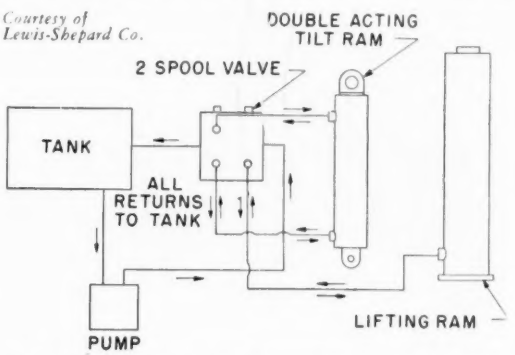


Figure 11 — Typical hydraulic circuit for a Fork Lift Truck.

course, there must be such auxiliary equipment as valves to control the flow of fluid and limit the amount of energy imparted to the fluid, a reservoir to contain a supply of the fluid, and lines to return the fluid to the reservoir after it has served its purpose.

HYDRAULIC SYSTEMS AS APPLIED TO INDUSTRIAL TRUCKS

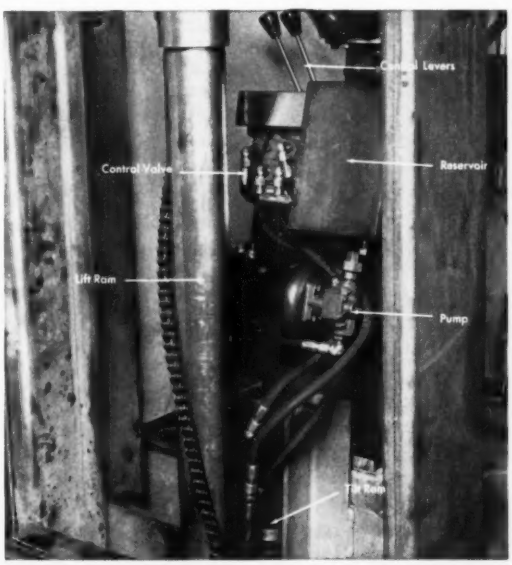
There are certain features which are basic and fundamental to the hydraulic systems of all industrial trucks, regardless of the type, make or number of handling operations involved. Some of the general characteristics and requirements of these components are discussed briefly as follows:

The Reservoir

Although the main purpose of the reservoir is to serve as a storage vessel for the hydraulic oil, it is actually much more than that. It is here that any air entering the system must escape; it is here that contaminants such as dirt and water must settle; and it is here that the heat content of the returning oil must be dissipated.

In order to satisfactorily accomplish these supplemental functions, the reservoirs must be designed with extreme care.

The reservoir design in an industrial truck is particularly critical. In most hydraulic installations space is not a factor and the capacities of the reservoirs are usually such that the hold-up time of the oil in the reservoir is relatively long. This facilitates the separation of air and contaminants and the removal of heat. However in the interest of keeping the overall size of an industrial truck to a minimum, the capacity of the reservoir is not any larger than necessary.



Courtesy of The Market Forge Co.

Figure 12—Hydraulic System in a Market Forge Fork Lift Truck.

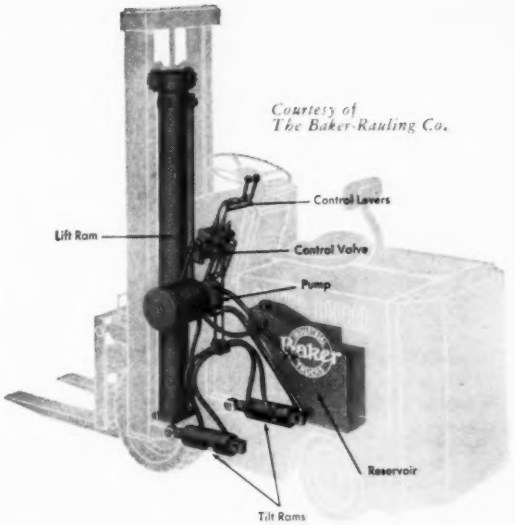
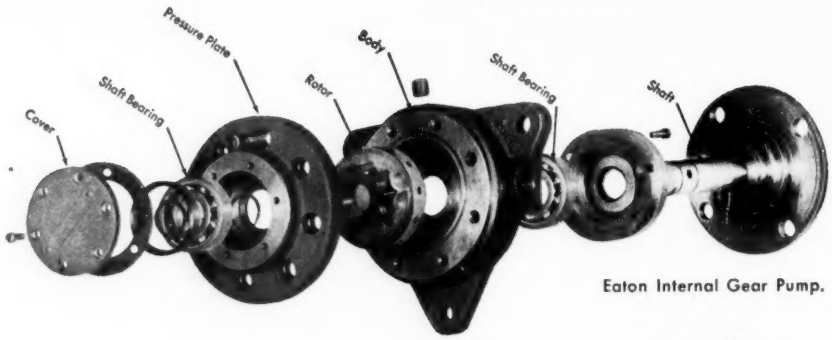


Figure 13 — Hydraulic System in a Baker Fork Lift Truck.

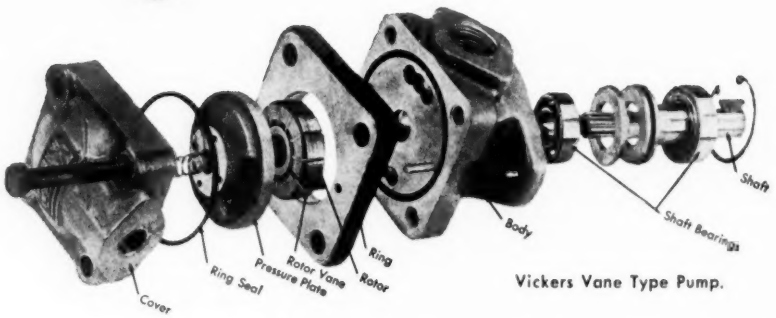
It is imperative that air be prevented from entering the pump suction line, as this would not only cause erratic operation of the hydraulic system but would also accelerate pump wear. Certain design features are observed wherever conditions permit in order to reduce the possibility that this will occur. For example, the reservoirs are usually deep and narrow, rather than shallow and wide, to minimize the chances of the oil level becoming so low as to approach the level of the pump intake. The pump suction line is located near the bottom of the reservoir in such a manner as to prevent the formation of a whirlpool such as occurs when water is drained from a bathtub. Such a condition would cause air to be drawn into the system. To reduce the tendency toward foam formation, which is another means whereby air can enter the pump, the line returning the oil to the reservoir usually extends well beneath the oil level and on the opposite side from the intake line. The incorporation of a vertical baffle in the reservoir, separating the pump intake from the oil return, is also frequently used to allow the oil returning to the vessel more time to separate contaminants and dissipate the heat before it is again picked up by the pump. As a further precaution that no solid contaminants in the reservoir enter the pump, a screen type filter is usually inserted in the intake line.

There will generally be a combination air vent and filler cap on top of the reservoir, and in order to keep atmospheric dust and other materials from entering, the cap will be equipped with a screen and an air filter. If the truck is operating in a particu-



Eaton Internal Gear Pump.

Courtesy of Clark Equipment Co.



Vickers Vane Type Pump.

Figure 14

larly moist atmosphere, a drier also is installed in the vent.

Pump

The pump is generally regarded as the heart of any hydraulic system because it is the pump which gives the fluid the force required to perform the mechanical work.

Most industrial trucks will use either vane type or gear type pumps with capacities ranging from 2 gpm to 70 gpm. Usually they will be required to develop pressures up to 1500 psi, although there are some trucks whose hydraulic systems operate in the neighborhood of 3000 psi. The pumps may be driven by a direct coupling, gear drive, or occasionally by "V" belts.

The gear type pumps operate on the simple principle that as the gears revolve, oil trapped between the gear teeth and the housing is carried from the suction side to the discharge side.

The vane pump consists essentially of a ring in which is located a smaller rotor with radial slots spaced around the circumference. Vanes are fitted in the slots in such a way that they are free to move in and out. As the rotor revolves the vanes are thrust against the outer ring forming an effective seal. Pumping is effected by locating the rotor and ring eccentric to each other.

Truck service imposes unusually heavy demands on the hydraulic pump. For example, it is frequently required to operate against relief valve pressures, and the sudden impact resulting therefrom puts a strain in the shaft and in the splines or keys that take the driving force. Also the radial load exerted by a gear or belt drive makes the pump bearings much more critical than in most applications.

Valves

The valves might well be regarded as the policemen of a hydraulic system because they direct and control the stream of oil as it travels throughout the hydraulic circuit. They are employed mainly to control (1) the direction of oil flow, (2) the volume of oil going to various parts of the system, and (3) the pressure of the oil at different points within the system. There are many types and varieties of valves available to accomplish these functions, and it is in their choice and selection that the truck manufacturers can exercise practically unlimited freedom and flexibility. Consequently, it would be a herculean task indeed to discuss in detail all of the combinations and modifications of valves currently used in the hydraulic systems of industrial trucks. However, they can be classified rather readily in general terms on the basis of the functions they are required to perform.

Release Valves

Some trucks are equipped to perform only one handling operation, such as raising and lowering a load, and it is here that a simple release valve can be employed. The load is raised by pumping oil from the reservoir to the hoist cylinder, is maintained in the elevated position by means of a check valve, and is lowered by depressing the treadle on the release valve, allowing the fluid to return to the reservoir. The valve is so constructed

that the lowering speed can be controlled by the force exerted on the treadle.

Direction Control Valves

For trucks capable of performing several independent operations, directing the flow of hydraulic fluid to and from the respective actuating cylinders is somewhat more complicated. In some installations separate valves are used to direct the flow of oil to each function involved. In others a single valve is used to control as many as six different operations. Such a valve usually contains movable spools which control the direction of flow by opening or closing certain ports or passages. These multiple spool valves can be one of two general types, parallel or series. With a parallel valve two or more functions can be performed simultaneously, as for example a load can be tilted at the same time it is being raised. With a series valve only one operation can be conducted at a time. In most cases pump delivery is constant and there is no time advantage for parallel operation over series, since the same amount of hydraulic fluid must be pumped to complete the motions whether they be carried out simultaneously or consecutively.

Each of the spools in a multifunctional valve will be attached to a lever controlled by the truck operator. When the levers are all in neutral positions, oil is merely pumped from the reservoir through the valve and back to the reservoir. However, when the lift lever, for example, is moved to the hoist position, the respective spool within the valve closes the return of oil to the reservoir and directs it under pressure to the lift cylinder. When the lever is returned to neutral position the load remains suspended at the height to which it had been raised and can not be lowered until the lift lever is moved to the proper position. With a parallel valve the operator could move the tilt lever and tilt the load while it was being raised. With a series valve the load could not be tilted until the lift lever was returned to neutral.

Another feature of the multiple spool valve is that it is usually so constructed that additional spools can be added. If, for example, a particular truck can only lift and tilt and it is desired to add another motion such as rotation, clamp or push-off, this additional motion can be controlled simply by incorporating another spool in the valve and connecting it to the new cylinder.

Relief Valves

These can be used to limit pressure in the hydraulic system to a predetermined maximum, thereby avoiding the danger of overloading the trucks and also the tendency for a particular motion to continue beyond its normal limit. The main relief or pressure-regulating valve controlling the pressure in the overall system is usually located in the directional control valve. If an operator in hoisting a load fails to return the lever to neutral when the maximum height has been reached, the system pressure will begin to increase and the relief valve will open, returning the fluid directly to the reservoir. The same thing would happen if the truck operator attempted to lift a load in excess of the rated maximum capacity of the truck.

Frequently, on operations such as clamping delicate loads, a secondary relief valve is provided to limit the clamping pressure to an amount which will enable the load to be grasped firmly but will not allow it to be crushed. This valve is usually placed in the secondary circuit beyond the main control valve and the pressure can be adjusted by the operator to the requirements of the load being handled. Pilot operated check valves are also used on clamping devices to assure that clamping pressure will be retained in case the hose connection is broken.

Flow Control Valves

Valves of this type are employed to control the speed of lowering a load within safe limits, and it is common practice for this valve to be installed inside of the hoist cylinder. If the hose connection to the hoist cylinder should rupture, the load will not drop, but will be lowered at a safe, controlled speed.

Cylinders

One of the features of a hydraulic system is that the force generated by the pump and controlled by suitable valves can easily be converted to mechanical motion at the place it is needed. Rotary, linear or reciprocating angular motion can be obtained by the use of suitable actuating cylinders or fluid motors.

Courtesy of The Yale and Towne Manufacturing Co.

Figure 15 — Directional Control Valve.

SINGLE HOSE CONNECTION
"SAFETY-FIRST" FLOW REGULATOR
SCRAPER EXCLUDES FOREIGN MATTER
MULTIPLE PACKINGS
Courtesy of The Yale and Towne Manufacturing Co.

Figure 16 — Section of a Hoist Cylinder.

Single and double-acting cylinders are the types commonly used on industrial trucks, although in telescopic operations the more complicated duplex type cylinders have to be employed. A simple actuating cylinder consists essentially of an enclosed tubular housing containing a piston and a rod connected to the piston and extending out one end of the head. In a single acting cylinder, oil pressure is applied to only one side of the piston. An example is a lift cylinder in which the load is raised by forcing oil to the under side of the piston but is lowered simply by the force of gravity. In a double-acting cylinder, oil pressure can be applied to either side of the piston, and the actuated part can be moved in either direction at will. The tilt cylinder on a truck is of this type.

Satisfactory performance of the cylinder depends, among other things, on the use of suitable packing both on the circumference of the piston and around the piston rod where it enters the cylinder.

These, then, are the basic units that compose the hydraulic system as used in the industrial truck to power the various material handling operations. They must be connected by suitable tubing, piping and fittings which are themselves equally as vital to the successful operation of the system. Although the location of the cylinders is more or less fixed, since they have to be placed at the site of the operation, the rest of the units are usually arranged to suit the fancy of the truck manufacturer.

THE HYDRAULIC OIL

Generally too little attention is given to the selection of the oil to be used in the hydraulic system. In most instances it is only required that the oil be of a suitable viscosity, and little or no consideration is given to any of its other properties.

Experience has shown that hydraulic systems, if treated with a reasonable amount of care, will seldom cause trouble. However, when trouble does occur, maintenance costs can be high. Although the causes of trouble can vary, the results of a recent survey indicate that *70 per cent are due to improper condition of the hydraulic oil*. What more forceful argument could be found to emphasize the importance of selecting the proper fluid? The Petroleum Industry, through continual research, has developed premium grade hydraulic oils, so designed as to have long life, keep the hydraulic systems clean and reduce the down time. It is a matter of record that the use of premium grade hydraulic oils will result in drastic reductions in maintenance costs.

BENEFITS FROM PREMIUM GRADE HYDRAULIC OILS

Let's look at a few of the benefits to be obtained by using the premium grade fluids in the hydraulic systems of the industrial trucks.

Oxidation Stability

Perhaps the largest single factor contributing to short oil life and poor operation of the hydraulic system is oxidation of the oil. The ultimate products of oxidation are gum, varnish and sludge, and their presence to even the slightest degree can be serious and costly. For example, even small amounts of sludge can cause the closely fitted parts in the

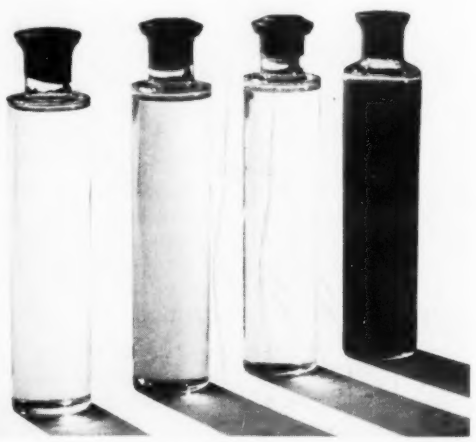


Figure 17—New and Oxidized Oils from ASTM Oxidation Test.
Left — New inhibited hydraulic oil.
Left Center — Same oil after 1000 hours, Neut. No. 0.1.
Right Center — New turbine grade straight mineral oil.
Right — Same oil after only 100 hours — Neut. No. 2.0.

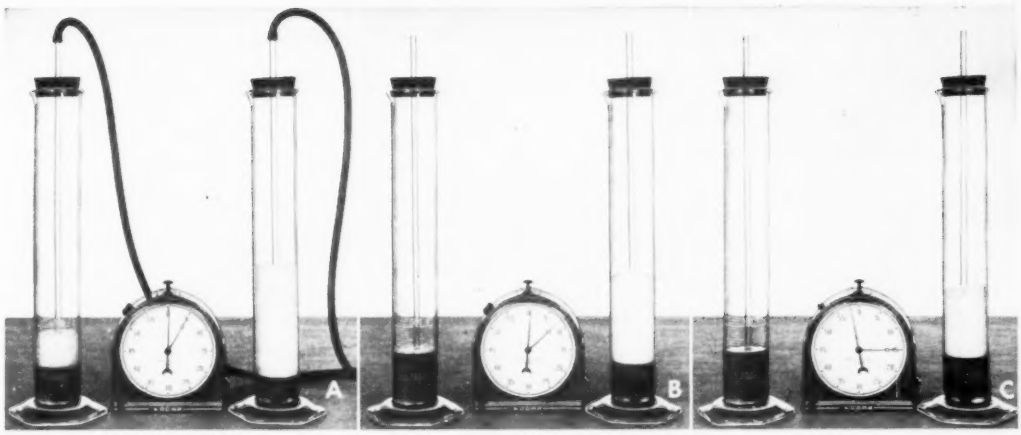


Figure 18 — Illustration of effect of foam depressants — oil on right of clock has no anti-foam agent.

pump to stick and the orifices in the valves to become plugged. They will also accelerate wear of the moving parts of the pump. Eventually the truck will have to be removed from service, so that the hydraulic system can be completely dismantled and mechanically cleaned and costly repairs made to the pump and valves.

Many factors can contribute to the oxidation of oils, including temperature, agitation, pressure and the catalytic effect of metals and contaminants. Practically all of these are present in any hydraulic system, but to an even greater degree in the industrial truck. For example, in materials handling operations heat is generated when a load is lowered. This heat is transmitted to the oil in the hoist cylinder and is subsequently carried to the reservoir. Because the reservoir is relatively small and the hold-up time short, the heat is not easily dissipated and the bulk oil temperature runs considerably higher than in most hydraulic installations. It is not uncommon for the oil temperature in the reservoir to average 165°F., and if the truck has been engaged for a long period in lowering heavy loads it may be considerably above this. Since temperature is a primary accelerator of oxidation and since the rate of oxidation above 140°F. is rather rapid, conditions in the hydraulic system of an industrial truck are very favorable for oil oxidation.

Premium grade hydraulic oils contain agents which inhibit oxidation, thereby increasing the life of the oil and keeping the system free from gum, sludge and varnish.

Rust Prevention

Frequently, industrial trucks operate in very moist atmospheres and in such cases a considerable amount of water may accumulate in the system. When water and ferrous metals are in contact, rusting can occur and hydraulic systems are by no means exempt. Just one or two flakes of rust passing through precision made pumps and valves can so scratch the surfaces that the efficiency of these parts is impaired.

Most premium grade hydraulic oils will contain additives that will allay rust formation, and by using such oils rusting in hydraulic systems can be prevented.

Foam Prevention

Whenever air and mineral oils are agitated together, conditions are favorable for the formation of foam. Such conditions exist in the reservoir of a hydraulic system and occasionally such a stable foam is formed that this air-oil emulsion is drawn through the pump and into the system. The deleterious effects of air in promoting pump wear and causing erratic action of the system have been discussed earlier.

Foaming can now be reduced to a negligible amount by certain types of additives which do not

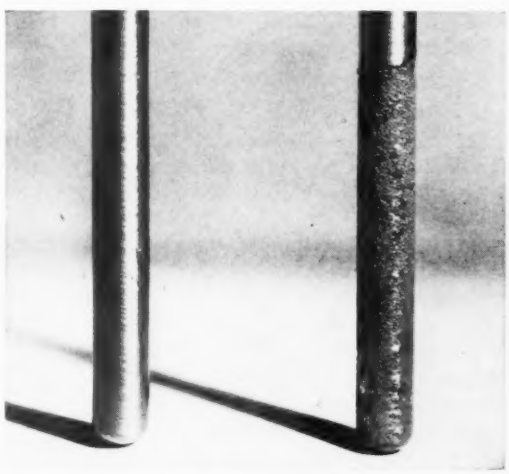


Figure 19 — Steel Rods from ASTM Rusting Test.
Rod on right obtained with straight mineral oil.
Rod on left obtained with inhibited hydraulic oil.

necessarily prevent the foam from forming but cause it to break rapidly. Premium grade oils will usually contain an anti-foam agent.

SUGGESTIONS ON PREVENTIVE MAINTENANCE

Often hydraulic systems of industrial trucks are checked only when the situation demands, due to leakage or failure of the system to operate. In such instances it is usually found that many things should have been attended to long before, in addition to the one which was immediately responsible for the unit being temporarily removed from service.

The hydraulic system is restored to good condition only at the expense of considerable time, labor and money.

Hydraulic mechanisms are precision units and their continued smooth operation depends upon proper care. The first step in any maintenance program should be the selection of the proper oil. It must be of suitable viscosity and to prevent oil oxidation, rust formation and foaming, and the problems associated therewith, it should contain rust and oxidation inhibitors and an anti-foam agent.

The selection of the proper oil is an excellent start, but to reduce the chances of trouble due to other causes, regular inspection periods should be established. Specific items to be checked include the following:

(1) Amount of fluid in the reservoir – this is particularly important on the industrial truck, due to the small size of the reservoir.
(2) Both internal and external leakage.
(3) The presence of dirt and other contaminants – in order to obtain full benefits from premium grade oils, system should be kept clean and free from external contamination.
(4) Mechanical damage to any of the components of the system.
(5) Improper adjustments of valves and pumps.
(6) Presence of air.

These are items which can easily be checked and should be done so rather frequently, preferably every one or two weeks. In addition it is desirable to make a more thorough examination of the various components of the hydraulic system at longer intervals. The frequency of such inspections should be determined by the type of service to which the truck is put and the conditions under which it has to operate. Normally these inspections should be made after every 1000 hours of service.

SUMMARY OF LUBRICATION REQUIREMENTS

This article has dealt only with the hydraulic system of the industrial truck and a discussion of the requirements for a satisfactory fluid to be used therein. Equally important, however, is the selection of proper lubricants and greases for other components of the truck.

Gasoline and Diesel Engines

Heavy duty motor oils containing special additives to impart the valuable properties of detergency and dispersion should be employed to assure better compression and combustion. The detergency keeps piston rings free and engine parts clean, and the dispersive ability holds deposit forming materials in suspension until drained. Such oils are so compounded as to resist oxidation and foaming, protect alloy bearings, and prevent scuffing of rings, pistons and cylinders.

Gear Boxes, Chain Drives and Universal Joints

For these applications, lubricants providing greater load carrying capacity and greater resistance to oxidation and thickening than straight mineral oils have been developed and should be employed. Such lubricants are able to withstand the shock loads experienced in the heaviest drives, thereby prolonging bearing life and reducing wear.

Grease Fittings, Plain Bearings and Anti-Friction Bearings

The bearings require a grease providing a tough adhesive film to cushion against shocks and make parts last longer. It must provide ideal film lubrication for ball and roller bearings and at the same time maintain its consistency at the outer edges.

An all purpose grease for normal operation should have a wide pumpability range and possess good water repellent characteristics.

Exposed Gears and Cables

The lubricants used on exposed gears are required to cushion load shocks, prevent noise and reduce wear. They must not channel or throw off, but cling to tooth surfaces and follow through from tooth to tooth despite high pressures, temperatures and peripheral speeds.

A satisfactory cable lubricant must be expected to penetrate and preserve the core, preventing collapse; seal each wire in a tough viscous film to reduce internal friction and wear; and keep out moisture to prevent corrosion and increase the life of the cable.

In addition to the use of properly selected lubricants and greases, the importance of good preventive maintenance practices is again stressed. Regularly scheduled lubrication periods, plus a periodic inspection and adjustment schedule is most essential for trouble-free operation and long truck life.

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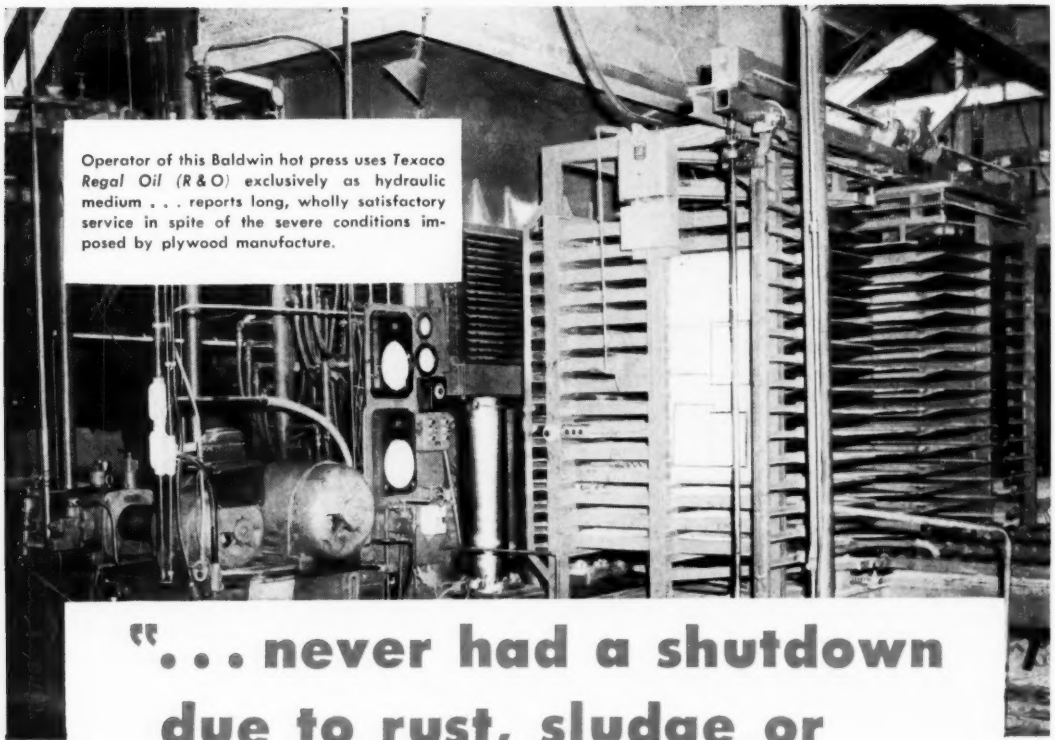
SIMPLIFIED LUBRICATION PLAN FOR INDUSTRIAL TRUCKS

PART REQUIRING LUBRICATION	TEMPERATURES	
	90-32° F.	32-10° F.
Gasoline and Diesel Engines	Texaco Ursa Oil Heavy Duty SAE 30 or Havoline Motor Oil SAE 30	Texaco Ursa Oil Heavy Duty SAE 20 or Havoline Motor Oil SAE 20
Gear Boxes Chain Drives Universal Joints	Texaco Universal Gear Lubricant EP 90 or Gear Lube HD 90	
Hydraulic Mechanisms Air Cleaners Electric Motors and Generators	Texaco Regal Oil PC (R&O)	Texaco Regal Oil AZ (R&O)
Grease Fittings Plain Bearings Anti-Friction Bearings	Texaco Marfak Heavy Duty 2 or Multifak 2	
Exposed Gears	Texaco Crater No. 2X	Texaco Crater No. 1X
Torque Converters Hydraulic Couplings	Texaco Torque Fluid or Texaco Texamatic Fluid	*(See a Texaco Lubrication Engineer for actual recommendation)*



Operator of this Baldwin hot press uses *Texaco Regal Oil (R & O)* exclusively as hydraulic medium . . . reports long, wholly satisfactory service in spite of the severe conditions imposed by plywood manufacture.

"... never had a shutdown due to rust, sludge or foam"... says leading Plywood Manufacturer*

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